Class VI UIC Area of Review and Corrective Action

This submission is for:

Project ID: R09-CA-0006

Project Name: San Joaquin Renewables

Current Project Phase: Pre-Injection Prior to Construction

Overview

Simulator Used for AoR delineation modeling: TOUGH2

Version Used: iTOUGH2

Simulator Description/Documentation: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0006/Phase1-PreConstruction/AoRModeling-11-01-2021-1407/qt0hn17903.pdf

Description of File Contents: Finsterle, S., Commer, M., Edmiston, J. K., Jung, Y., Kowalsky, M. B., Pau, G. S. H., ... &Zhang, Y. (2017). iTOUGH2: A multiphysics simulation-optimization framework for analyzing subsurface systems. Computers &Geosciences, 108, 8-20.

Total Simulation Time From Start of Injection: 115 yrs

Additional AoR Delineation Information: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0006/Phase1-PreConstruction/AoRModeling-11-01-2021-1407/Additional--AoR--Delineation--Information.txt

Description of Information Submitted: Not applicable, EPA has primacy for Class VI in California.

Model Domain

Coordinate System: UTM

Horizontal Datum: NAD27

Coordinate System Units: m

Vertical Datum: Mean Sea Level

Describe Vertical Datum: NAVD 88

Zone: 11

Mesh Type: Other

Describe Mesh Type: Unstructured Voronoi mesh with variable number of elements in x, y and z directions

Domain Size in Global Units Specified Above

Domain Coordinates File: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0006/Phase1-PreConstruction/AoRModeling-11-01-2021-1407/AoRModeling_DomainCoord_SanJoaquin.xlsx

Grid Size

Number of Nodes in x: 140392 y: 1 z: 1

Grid Spacing: Variable

Grid File Format: ASCII file containing vertices and elements

Grid File Description: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0006/Phase1-PreConstruction/AoRModeling-11-01-2021-1407/MeshGeneration.docx

Grid Data File: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0006/Phase1-PreConstruction/AoRModeling-11-01-2021-1407/MESH-Frontline.txt

Faults Modeled: Yes

Fault Coordinates File: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0006/Phase1-PreConstruction/AoRModeling-11-01-2021-1407/Frontline_Faults.xlsx

Caprock Modeled: Yes

Image File(s) for Model Domain Grid: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0006/Phase1-PreConstruction/AoRModeling-11-01-2021-1407/MeshImages.docx

Model Domain Comments: A three-dimensional, unstructured Voronoi mesh (in TOUGH2 format) is generated within the bounding box described above. The surface mesh has a radial geometry in the vicinity of the injection well, morphing to a rectangualr mesh with increasing element sizes. Fault traces are included. The unstructured surface mesh is repeated in the vertical direction to create columns. Vertical resolution is uniformly 5 m. The model is vertically truncated 50 m below the bottom of the main injection formation (Vedder) and 50 m above the uppermost caprock (Olcese) or the land surface. The mesh has aprpoximately 140,000 elements and 432,000 connections between them. Grid size node numbers above are placeholders, as we used an unstructured mesh and therefore the question is not applicable.

Processes Modeled by Simulator

Reservoir Conditions:

Supercritical CO2 Conditions

Phases Modeled:

Aqueous Supercritical CO2

Aqueous Phase:

Phase Compressibility: Compressible

Compressibility Value: 4.4 1/Pa

Phase Composition: Compositional

Aqueous Phase Components:

CO2 Water Salt

Supercritical CO2 Phase:

Phase Compressibility: Compressible

Phase Composition: Compositional

Supercritical CO2 Phase Components:

CO2 Water

Equation of State Description Including Reference: General description: Pruess, K., ECO2N: A TOUGH2 Fluid Property Module for Mixtures of Water, NaCl, and CO2, Report LBNL-57952, Lawrence Berkeley National Laboratory, Berkeley, CA, 2005. Water properties: International Association for the Properties of Water and Steam: Revised Release on the IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam, IAPWS Release, Switzerland, (2007). CO2 properties: Altunin, V.V. Thermophysical Properties of Carbon Dioxide, Publishing House of Standards, 551 pp., Moscow, 1975. NaC/brine propertiesl: Battistelli, A., C. Calore and K. Pruess. The Simulator TOUGH2/EWASG for Modeling Geothermal Reservoirs with Brines and Non-Condensible Gas, Geothermics, Vol. 26, No. 4, pp. 437 - 464, 1997.

File with EOS Reference or Documentation: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0006/Phase1-PreConstruction/AoRModeling-11-01-2021-1407/TOUGH2-ECO2N_Users_Guide.pdf

Multifluid Flow Processes:

Advection Diffusion Buoyancy

Non-wetting Fluid Trapping Pore Compressibility

Thermal Conditions: Isothermal

Heat Transport Processes:

Geochemistry Modeled: No

Geomechanical/Structural Deformations Modeled: No

Modeled Processes Comments: The evolution of (a) the free-phase plume of supercritical carbon dioxide (scCO2), (b) the pressure buildup induced by CO2 injection, and (c) the associated brine displacement are predominantly hydrogeological flow and transport processes, which are appropriately described by the multiphase flow formulation of the TOUGH2 simulator. In particular, injected CO2 flows through the geologic formation in response to pressure and viscous forces, accounting for capillary pressure effects and phase interferences described by relative permeabilities for both the aqueous and CO2-rich phases. As injection proceeds, a buoyant CO2 plume evolves, which may become trapped in larger-scale geological structures (referred to as structural trapping). An accurate representation of the main geological and hydrostratigraphic structures is therefore essential, along with an accurate calculation of the thermophysical properties of the fluid mixtures, which is provided by TOUGH2. On the small scale, the gas phase may also become discontinuous and get trapped in certain portions of the pore space (referred to as phase trapping or hydraulic trapping). The use of an effective residual gas saturation in the relative permeability functions or a fully hysteretic retention model account for these phase-trapping mechanisms. Moreover, CO2 dissolves in the aqueous phase, increasing its density and potentially leading to gravity-driven downwards migration. Finally, geochemical reactions may take place that bind (and thus immobilize) CO2 into carbonate minerals. However, mineralization is typically a slow, long-term geochemical reaction, which is conservatively neglected in these simulations. Geochemical reactions are therefore limited to phase partitioning of the three components, water, CO2 and NaCl, including the potential precipitation of solid salt as the injected CO2 dries out the native brine. The injection of large amounts of CO2 may lead to significant overpressures (specifically near the injection well). The expansion or compression of the pore space in response to changes in fluid pressures is accounted for through an elastic pore compressibility. The temperature within the model domain increases with depth. However, assuming that the temperature of the injected CO2 is identical to the formation temperature, the simulations are performed in isothermal mode (i.e., the temperature does not vary with time).

Rock Properties and Constitutive Relationships

Porosity/Permeability Model

Single Porosity

Porosity Distribution: Heterogeneous

Spatially Variable Porosity File: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0006/Phase1-PreConstruction/AoRModeling-11-01-2021-1407/T1-1_Smmry-Porosity.pdf

File Describing how Porosity was Determined and Assigned to Numerical Model: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0006/Phase1-PreConstruction/AoRModeling-11-01-2021-1407/Conceptual--Model--from--AoR--Plan_por.pdf

Image Files for Porosity Distributions: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0006/Phase1-

PreConstruction/AoRModeling-11-01-2021-1407/Porosity--Distribution.txt

Permeability Distribution: Heterogeneous

Spatially Variable Permeability File: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0006/Phase1-PreConstruction/AoRModeling-11-01-2021-1407/T1-1_Smmry-Prmblty.pdf mD

File Describing how Permeability was Determined and Assigned to Numerical Model: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0006/Phase1-PreConstruction/AoRModeling-11-01-2021-1407/Conceptual--Model--from--AoR--Plan_perm.pdf

Image Files for Permeability Distributions: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0006/Phase1-PreConstruction/AoRModeling-11-01-2021-1407/Fig_1-5--Permeability--Cross--Section.pdf

Number of Rock Types Modeled: 9

Description of Rock Type Selection and Assignment: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0006/Phase1-PreConstruction/AoRModeling-11-01-2021-1407/Numerical--Mesh--Implementation--from--AoR--Plan.pdf

Rock Type Distribution Data File: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0006/Phase1-PreConstruction/AoRModeling-11-01-2021-1407/Rocks--distribution.zip

Image Files for Rock Type Distribution: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0006/Phase1-PreConstruction/AoRModeling-11-01-2021-1407/Rocks--images.zip

Rock Type #1

Rock Compressibility: Pore

Rock Compressibility Distribution: Single Value

Compressibility Value: 0.00001 1/psi

Constitutive Relationships

Aqueous Saturation vs. Capillary Pressure: Functional Form

File Describing Functional Form Used for Aqueous Saturation vs Capillary Pressure: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0006/Phase1-PreConstruction/AoRModeling-11-01-2021-1407/Pages--from--AoR--plan_RM.pdf

Aqueous Trapped Gas Modeled: No

Hysteresis other than non-wetting fluid trapping: No

Aqueous Relative Permeability: Functional Form

File Describing Functional Form Used for Aqueous Relative Permeability: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0006/Phase1-PreConstruction/AoRModeling-11-01-2021-1407/explanation_RM_ARP.txt

Hysteresis other than non-wetting fluid trapping: No

Gas Relative Permeability: Functional Form

File Describing Functional Form Used for Gas Relative Permeability: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0006/Phase1-PreConstruction/AoRModeling-11-01-2021-1407/explanation_RM_GRP.txt

Hysteresis other than non-wetting fluid trapping: No

Porosity and Permeability Reduction Due to Salt Precipitation

Rock Type #2

Rock Compressibility: Pore

Rock Compressibility Distribution: Single Value

Compressibility Value: 0.000003 1/psi

Constitutive Relationships

Aqueous Saturation vs. Capillary Pressure: Functional Form

File Describing Functional Form Used for Aqueous Saturation vs Capillary Pressure: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0006/Phase1-PreConstruction/AoRModeling-11-01-2021-1407/Pages--from--AoR--plan_Olcese.pdf

Aqueous Trapped Gas Modeled: No

Hysteresis other than non-wetting fluid trapping: No

Aqueous Relative Permeability: Functional Form

File Describing Functional Form Used for Aqueous Relative Permeability: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0006/Phase1-PreConstruction/AoRModeling-11-01-2021-1407/explanation_OI_ARP.txt

Hysteresis other than non-wetting fluid trapping: No

Gas Relative Permeability: Functional Form

File Describing Functional Form Used for Gas Relative Permeability: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0006/Phase1-PreConstruction/AoRModeling-11-01-2021-1407/explanation_OI_GRP.txt

Hysteresis other than non-wetting fluid trapping: No

Porosity and Permeability Reduction Due to Salt Precipitation

Rock Type #3

Rock Compressibility: Pore

Rock Compressibility Distribution: Single Value

Compressibility Value: 0.00001 1/psi

Constitutive Relationships

Aqueous Saturation vs. Capillary Pressure: Functional Form

File Describing Functional Form Used for Aqueous Saturation vs Capillary Pressure: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0006/Phase1-PreConstruction/AoRModeling-11-01-2021-1407/Pages--from--AoR--plan_FJ.pdf

Aqueous Trapped Gas Modeled: No

Hysteresis other than non-wetting fluid trapping: No

Aqueous Relative Permeability: Functional Form

File Describing Functional Form Used for Aqueous Relative Permeability: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0006/Phase1-PreConstruction/AoRModeling-11-01-2021-1407/explanation_FJ_ARP.txt

Hysteresis other than non-wetting fluid trapping: No

Gas Relative Permeability: Functional Form

File Describing Functional Form Used for Gas Relative Permeability: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0006/Phase1-PreConstruction/AoRModeling-11-01-2021-1407/explanation_FJ_GRP.txt

Hysteresis other than non-wetting fluid trapping: No

Porosity and Permeability Reduction Due to Salt Precipitation

Rock Type #4

Rock Compressibility: Pore

Rock Compressibility Distribution: Single Value

Compressibility Value: 0.000003 1/psi

Constitutive Relationships

Aqueous Saturation vs. Capillary Pressure: Functional Form

File Describing Functional Form Used for Aqueous Saturation vs Capillary Pressure: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0006/Phase1-PreConstruction/AoRModeling-11-01-2021-1407/Pages--from--AoR--plan_PYDH-VED1-VED2.pdf

Aqueous Trapped Gas Modeled: No

Hysteresis other than non-wetting fluid trapping: No

Aqueous Relative Permeability: Functional Form

File Describing Functional Form Used for Aqueous Relative Permeability: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0006/Phase1-PreConstruction/AoRModeling-11-01-2021-1407/explanation_VED1_ARP.txt

Hysteresis other than non-wetting fluid trapping: No

Gas Relative Permeability: Functional Form

File Describing Functional Form Used for Gas Relative Permeability: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0006/Phase1-PreConstruction/AoRModeling-11-01-2021-1407/explanation_VED1_GRP.txt

Hysteresis other than non-wetting fluid trapping: No

Porosity and Permeability Reduction Due to Salt Precipitation

Rock Type #5

Rock Compressibility: Pore

Rock Compressibility Distribution: Single Value

Compressibility Value: 0.00001 1/psi

Constitutive Relationships

Aqueous Saturation vs. Capillary Pressure: Functional Form

File Describing Functional Form Used for Aqueous Saturation vs Capillary Pressure: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0006/Phase1-PreConstruction/AoRModeling-11-01-2021-1407/Pages--from--AoR--plan_VED2SH.pdf

Aqueous Trapped Gas Modeled: No

Hysteresis other than non-wetting fluid trapping: No

Aqueous Relative Permeability: Functional Form

File Describing Functional Form Used for Aqueous Relative Permeability: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0006/Phase1-PreConstruction/AoRModeling-11-01-2021-1407/explanation_VED2SH_ARP.txt

Hysteresis other than non-wetting fluid trapping: No

Gas Relative Permeability: Functional Form

File Describing Functional Form Used for Gas Relative Permeability: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0006/Phase1-PreConstruction/AoRModeling-11-01-2021-1407/explanation_VED2SH_GRP.txt

Hysteresis other than non-wetting fluid trapping: No

Porosity and Permeability Reduction Due to Salt Precipitation

Rock Type #6

Rock Compressibility: Pore

Rock Compressibility Distribution: Single Value

Compressibility Value: 0.000003 1/psi

Constitutive Relationships

Aqueous Saturation vs. Capillary Pressure: Functional Form

File Describing Functional Form Used for Aqueous Saturation vs Capillary Pressure: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0006/Phase1-PreConstruction/AoRModeling-11-01-2021-1407/Pages--from--AoR--plan_VED3.pdf

Aqueous Trapped Gas Modeled: No

Hysteresis other than non-wetting fluid trapping: No

Aqueous Relative Permeability: Functional Form

File Describing Functional Form Used for Aqueous Relative Permeability: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0006/Phase1-PreConstruction/AoRModeling-11-01-2021-1407/explanation_VED3_ARP.txt

Hysteresis other than non-wetting fluid trapping: No

Gas Relative Permeability: Functional Form

File Describing Functional Form Used for Gas Relative Permeability: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0006/Phase1-PreConstruction/AoRModeling-11-01-2021-1407/explanation_VED3_GRP.txt

Hysteresis other than non-wetting fluid trapping: No

Porosity and Permeability Reduction Due to Salt Precipitation

Rock Type #7

Rock Compressibility: Pore

Rock Compressibility Distribution: Single Value

Compressibility Value: 0.000003 1/psi

Constitutive Relationships

Aqueous Saturation vs. Capillary Pressure: Functional Form

File Describing Functional Form Used for Aqueous Saturation vs Capillary Pressure: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0006/Phase1-PreConstruction/AoRModeling-11-01-2021-1407/Pages--from--AoR--plan_VED4.pdf

Aqueous Trapped Gas Modeled: No

Hysteresis other than non-wetting fluid trapping: No

Aqueous Relative Permeability: Functional Form

File Describing Functional Form Used for Aqueous Relative Permeability: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0006/Phase1-PreConstruction/AoRModeling-11-01-2021-1407/explanation_VED4_ARP.txt

Hysteresis other than non-wetting fluid trapping: No

Gas Relative Permeability: Functional Form

File Describing Functional Form Used for Gas Relative Permeability: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0006/Phase1-PreConstruction/AoRModeling-11-01-2021-1407/explanation_VED4_GRP.txt

Hysteresis other than non-wetting fluid trapping: No

Porosity and Permeability Reduction Due to Salt Precipitation

Rock Type #8

Rock Compressibility: Pore

Rock Compressibility Distribution: Single Value

Compressibility Value: 0.00001 1/psi

Constitutive Relationships

Aqueous Saturation vs. Capillary Pressure: Functional Form

File Describing Functional Form Used for Aqueous Saturation vs Capillary Pressure: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0006/Phase1-PreConstruction/AoRModeling-11-01-2021-1407/Pages--from--AoR--plan_VED4SH.pdf

Aqueous Trapped Gas Modeled: No

Hysteresis other than non-wetting fluid trapping: No

Aqueous Relative Permeability: Functional Form

File Describing Functional Form Used for Aqueous Relative Permeability: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0006/Phase1-PreConstruction/AoRModeling-11-01-2021-1407/explanation_VED4SH_ARP.txt

Hysteresis other than non-wetting fluid trapping: No

Gas Relative Permeability: Functional Form

File Describing Functional Form Used for Gas Relative Permeability: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0006/Phase1-PreConstruction/AoRModeling-11-01-2021-1407/explanation_VED4SH_GRP.txt

Hysteresis other than non-wetting fluid trapping: No

Porosity and Permeability Reduction Due to Salt Precipitation

Rock Type #9

Rock Compressibility: Pore

Rock Compressibility Distribution: Single Value

Compressibility Value: 0.000016 1/psi

Constitutive Relationships

Aqueous Saturation vs. Capillary Pressure: Functional Form

File Describing Functional Form Used for Aqueous Saturation vs Capillary Pressure: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0006/Phase1-PreConstruction/AoRModeling-11-01-2021-1407/Pages--from--AoR--plan_Walker.pdf

Aqueous Trapped Gas Modeled: No

Hysteresis other than non-wetting fluid trapping: No

Aqueous Relative Permeability: Functional Form

File Describing Functional Form Used for Aqueous Relative Permeability: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0006/Phase1-PreConstruction/AoRModeling-11-01-2021-1407/explanation_Walker_ARP.txt

Hysteresis other than non-wetting fluid trapping: No

Gas Relative Permeability: Functional Form

File Describing Functional Form Used for Gas Relative Permeability: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0006/Phase1-PreConstruction/AoRModeling-11-01-2021-1407/explanation_Walker_GRP.txt

Hysteresis other than non-wetting fluid trapping: No

Porosity and Permeability Reduction Due to Salt Precipitation

Rock Properties Comments: Relative permeability and capillary pressure parameters are only relevant where two-phase (aqueous-gas) conditions prevail, i.e., within the Upper Vedder (PYDH-VED1-VED2). Therefore, this information is not applicable to most ROCK types.

Boundary Conditions

Attach Boundary Conditions Description File: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0006/Phase1-PreConstruction/AoRModeling-11-01-2021-1407/Boundary--Conditions--from--AoR--Plan.pdf

Initial Conditions

Initial Phases in Domain: Aqueous

Initial Aqueous Pressure: Spatially Variable

Spatially Variable Initial Aqueous Pressure File: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0006/Phase1-PreConstruction/AoRModeling-11-01-2021-1407/InitialP.csv

Initial Temperature: Spatially Variable

Spatially Variable Initial Temperature File: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0006/Phase1-PreConstruction/AoRModeling-11-01-2021-1407/InitialT.csv

Initial Salinity: Spatially Variable

Spatially Variable Salinity File: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0006/Phase1-PreConstruction/AoRModeling-11-01-2021-1407/Initial--Salinity.zip

Initial Condition Comments: See AoR and Corrective Action Plan section 1.4.2

Operational Information

Number of Injection Wells: 1

Injection Well #1

Well Direction: Vertical

Location: X: 294000 UTM Y: 3951600 UTM

Wellbore Diameter: Variable

Wellbore Diameter File: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0006/Phase1-PreConstruction/AoRModeling-11-01-2021-1407/Fig_3-1_Injection--Well--Design.pdf

Well Screen Interval Provided as: Multiple Intervals

Screened Interval File: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0006/Phase1-PreConstruction/AoRModeling-11-01-2021-1407/Well--screen--interval.txt

Mass Rate of Injection: 1200 MT/day

Total Mass of Injection: 6570000 MMT

Fracture Gradient: 0.66 psi/ft

Maximum Injection Pressure: 480000 Pa Elevation Corresponding to Pressure: 7775 m

Description of How Fracture Gradient and Maximum Injection Pressure were Determined: Attached file describes the fracture gradient calculation. Maximum pressure was obtained from TOUGH2 modeling.

Description of How Fracture Gradient and Maximum Injection Pressure were Determined File: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0006/Phase1-PreConstruction/AoRModeling-11-01-2021-1407/Appendix--F--Fracture--Gradient--Calculation.docx

Composition of Injectate: Pure CO2

Injection Schedule Provided as: Single Injection Period

Injection Start Date: 01/01/2024 Stop Date: 01/01/2039

Number of Production/Withdrawal Wells: 0

Operational Information Comments: 1,200 tons/day injection for 15 years; injectate impurties concentrations given in AoR and Corrective Action Plan. Injection start and end dates are estimated based on a 15 year injection timeframe.

Model Output/Results

Provide file name and corresponding spatial location for each file: The AOR is determined from "snapshot data" of CO2 saturation and pressure calculated at all model points (see "Snapshot data" below). TimeSeries.zip contains: - BalanceVsTime.csv: csv file with total CO2 volume (m^3), CO2 mass in gas phase (kg), CO2 mass dissolved in aqueous phase, and total CO2 mass (kg) as a function of time (sec) -BalanceVsTime.jpg: Plot of data from BalanceVsTime.csv

Time-Series File: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0006/Phase1-PreConstruction/AoRModeling-11-01-2021-1407/TimeSeries.zip

Provide file name and corresponding variable and time stamp for each file: Ink1base.zip contains i=1..11 csv snapshot files Inj1base_XYZ_000i_TIME.csv for time TIME (years). Each file contains the following variables for each grid block within the model domain: material number, X (m), Y (m), Z (m), gas pressure (Pa), delta pressure (Pa), admissible pressure (Pa), overpressure - admissible pressure (Pa), gas saturation (-), NaCl mass fraction in aquesou phase (-), CO2 mass fraction in aqeuous phase, gas flow rate components (kg/s/m^2), liquid flow rate components (kg/s/m^2), absolute permeability components (m^2), porosity (-), relative gas permeability (-), gas density (kg/m^3), gas viscosity (Pa s).

Snapshot File: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0006/Phase1-PreConstruction/AoRModeling-11-01-2021-1407/Snapshot.zip

Provide file name and corresponding description of surface for each file: Flux information is provided in the snapshot file uploaded above

Surface Flux File: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0006/Phase1-PreConstruction/AoRModeling-11-01-2021-1407/Surface--Flux--File.txt

Sensitivity Analysis Description/Results: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0006/Phase1-PreConstruction/AoRModeling-11-01-2021-1407/SensitivityAnalysisDescription.pdf

Model Output Comments: Full (i)TOUGH2 simulation output files for reference case and 12 sensitivity analyses are available.

AoR Pressure Front Delineation

Lowermost USDW:

Name of Lowermost USDW: Alluvium

Water Density: 994 kg/m^3 at Elevation: -640 m

Location of Measurement for Density: Injection Well (assumed)

Temperature: 37.4 C at Elevation: -640 m

Location of Measurement: Injection Well (assumed)

Pressure: 7.2 MPa at Elevation: -640 m

Location of Measurement: Injection Well (assumed)

Salinity: 500 mg/L at Elevation: -640 m

Location of Measurement: Injection Well (assumed)

Elevation of bottom of USDW: -640 m

Injection Zone:

Name of Injection Zone: Vedder

Water Density: 992 kg/m^3 at Elevation: -2252 m

Location of Measurement: Injection Well (assumed)

Temperature: 77.7 C at Elevation: -2252 m

Location of Measurement: Injection Well (assumed)

Pressure: 25.95 MPa at Elevation: -2252 m

Location of Measurement: Injection Well (assumed)

Salinity: 25000 mg/L at Elevation: -2252 m

Location of Measurement: Injection Well (assumed)

Elevation of top of Injection Zone: -2252 m

Method of Estimating Critical Pressure: Other

File Describing Critical Pressure Estimation: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0006/Phase1-PreConstruction/AoRModeling-11-01-2021-1407/Pressure--Front.zip

Estimated Critical Pressure: 142622 Pa

Delineated AoR:

Shapefile or KML File Showing Delineated AoR: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0006/Phase1-PreConstruction/AoRModeling-11-01-2021-1407/AoR.zip

AoR Pressure Front Delineation Comments: Critical pressure values are variable throughout the domain (as explained in documentation), value given is at the injection well (X 294000 Y 3951600) and is a 'delta pressure', or the increase in pressure required.

Corrective Action

File with Location of All Penetrations within AoR: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0006/Phase1-PreConstruction/AoRModeling-11-01-2021-1407/Artificial--Penetrations_all.csv

File with Location of Wells Requiring Corrective Action: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0006/Phase1-PreConstruction/AoRModeling-11-01-2021-1407/Artificial--Penetrations_CA.csv

Supporting Documentation: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0006/Phase1-PreConstruction/AoRModeling-11-01-2021-1407/Plugging--Records.zip

Area of Review and Corrective Action Plan [40 CFR 146.82(a)(13) and 146.84(b) or applicable state requirements]

Are you making an Area of Review and Corrective Action Plan submission at this time?: Yes

Reason for Project Plan Submission: Permit application submission

Project Plan Upload

Attach the Area of Review and Corrective Action Plan: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0006/Phase1-PreConstruction/AoRModeling-11-01-2021-1407/3_AoR--Corrective--Action_101321.pdf

Appendices and Supporting Materials Upload

Area of Review Reevaluation [40 CFR 146.84(e) or applicable state requirements]

Minimum fixed frequency of AoR reevaluation: 5 Years

Are you making an Area of Review reevaluation submission at this time?: No

Reevaluation Background

Reevaluation Materials

Please upload your amended AoR and Corrective Action Plan on the previous tab.

Complete Submission

Authorized submission made by: Thomas Paskach

For confirmation a read-only copy of your submission will be emailed to: gschnaar@geo-logic.com